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August 29, 1995

H.E. Kumpf and A.C. Jones, Editors

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INTRODUCTION

The 125th Annual American Fisheries Society (AFS) meeting held in Tampa, Florida, from August 28-30, 1995 had the theme of "Fisheries: A Vision for the Future-Science, Application, Communication." As part of this theme a special program, "Bridges to Mexico" was planned and sponsored by the International Fisheries Section of the AFS. A special symposium was organized by Herman E. Kumpf. One objective of the symposium was to facilitate the expected increase in the cooperative efforts between Mexico and the United States stemming from the passage of the North American Free Trade Agreement (NAFTA).

A Brief History:

Cooperative efforts in Gulf of Mexico fishery research between the United States and Mexico have operated since the 1970s under a MEXUS-Gulf program. The first MEXUS-Gulf meeting was held in Campeche, Mexico, in 1977 as a set of cooperative research working groups to address specific problems in fisheries. In the ensuing years, alternative meeting sites (southeastern United States and Mexico) were used by mutual agreement. Each annual meeting would incorporate an initial session of information presentations of the previous year's research results. In addition, cooperative research activities would be planned, mutually supported and agreements reached. Initial working groups included: plankton, shrimp, demersal fisheries, coastal fisheries, pollution, sea turtles, and hydroacoustics. Mutual fishery research interests have fluctuated only slightly, with some groups added as well as some working groups dropped. The present working groups, reflected in this symposium, include shrimp, coastal pelagics, sea turtles, demersal fisheries and fishing gear technology.

Symposium Format:

The MEXUS-Gulf Cooperative Fisheries Research Program-A Decade of Progress Symposium took place on Tuesday, August 29, 1995 and was convened by Dr. Bradford Brown, Director, Southeast Fisheries Science Center, National Marine Fisheries Service, and Dr. Pablo Arenas, Research Director, Instituto Nacional de la Pesca.

The usual procedures for MEXUS-Gulf meetings were followed with an initial joint technical presentation by working group members. This year's meeting used the venue of the annual American Fisheries Society's "Bridges to Mexico" program to present more formal fishery research papers jointly authored by United States and Mexican scientists.

This Technical Memorandum contains the research papers as presented and constitutes the proceedings of the 1995 MEXUS-Gulf meeting.

The editors thank the authors and conveners for their contributions and continued interest.

Editors: Herman E. Kumpf and Albert C. Jones

Recovery of Kemp's Ridley Sea Turtle Population at the Mexican Beach of Rancho Nuevo, Tamaulipas

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Resume

La tortuga lora *(Lepidochelys kempii,* Garman, 1880) es una especie endemica del Golfo de Mexico, cuya area de reproduccion esta circunscrita a la playa de Rancho Nuevo, Tamps. La abundancia de las hembras que llegan a la playa ha presentado variaciones muy amplias en el lapso 1966-1994, periodo en el que esta area se ha protegido durante la temporada de anidacion. El menor numero de nidos se observo en 1987 (748), mientras que por el contrario, en 1994 se estimo la mayor cantidad (1,545). Es necesario indicar que desde 1991 se cuenta con dos campamentos adicionales (Ostionales y Barra del Tordo) y esto ha permitido proteger mas nidos. Sobre la base de estos datos es posible estimar un incremento significativo en la tasa de sobrevivencia de las hembras (S = 0.967-1.022) y un descenso en la mortalidad (de z = 0.0331 to -0.0218) para el intervalo 1987-1994. La misma tendencia se observa si solo se consideran los resultados de Rancho Nuevo, aunque menos pronunciada.

La recuperacion de la poblacion tambien es coadyuvada por la implementacion del uso de los dispositivos excluidores de tortugas (DET) en barcos camaroneros, desafortunadamente en 1993. llegaron 13 tortugas muertas a Rancho Nuevo, mientras que en 1994 encallaron 457 tortugas loras al litoral atlantico estadounidense. Aunque es dificil determinar con certeza la causa de la muerte, esta posiblemente sea consecuencia de la captura incidental durante la pesca de camaron. Por lo tanto, a pesar del exito de las campanas de proteccion en la playa es necesario incrementar estos esfuerzos en el medio marino.

Introduction

Variation in the annual number of nesting females is typical but if there is an increasing trend over several years, this could signal that the population is recovering. This increasing trend has been observed for the Kemp's ridley turtle *(Lepidochelys kempii)* nesting on the Mexican beaches of Rancho Nuevo over the past seven years.

Rancho Nuevo, Tamaulipas, on the northeast seaboard of Mexico is known as the most important nesting beach for the Kemp's ridley sea turtle. Every year from March to July a portion of the adult females come to this area to lay hundreds of eggs. From April to September the hatchlings enter the waters of the Gulf of Mexico and disappear for at least a decade, before the females return to nest to the same place. To study and protect this population, in 1966 a conservation program was initiated by the Mexican government. Because this species is found in US waters also, in 1978 the US joined Mexico in this program. This program is considered one of the most successful binational efforts and some results from nesting beach protection are presented in Table 1.

Included in Table 1 are the annual total nests estimated, the numbers of nests moved to protective corrals or penned

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areas on the beaches, the number of nests left on the beach unprotected (in situ), the numbers of nests moved in total to styrofoam boxes, the number of nests predated, the number of nests donated for research purposes and the total numbers of eggs and hatchlings in the thousands. It represents the time series since 1966. In 1947 it had been estimated that over 40,000 turtles were observed at one time (an "arribada," Carr, 1963) which is considered a peak in the known time series with a decline to an arribada of about 2,000 females by 1968 (Marquez et al., 1994). A low number for arrivals in Rancho Nuevo, Tamaulipas, was observed in 1987, with an estimated total number of 748 nests. Since 1987, the total number of nests has been steadily increasing and the total number of nests during 1994 is comparable to the estimate of about 20 years ago.

In 1989, another camp was installed in Barra del Tordo, 13.4 km south of the main camp at Rancho Nuevo, and a dozen nests were protected. In 1990 a third camp was installed 25.2 km north from the Rancho Nuevo Station in Boca de Ostionales. In 1991 these two extra camps were officially settled and consequently today the patrolled area is over 100 km. These camps have only four or five years of complete observations. However, the numbers of nests, particularly in "Ostionales" show a positive trend (Figure 1).

Log linear regressions were completed for the total estimated number of nests for Rancho Nuevo only by year using the years 1990, 1991, 1992, and 1993 as the terminal years and all beginning with the year 1978 (Figure 2). Log linear regressions were also completed in the same way incorporating the nest totals for the two added beach areas (Figure 3). The slope of these regressions represent the rate of change in number of nests over the time series, based on the log transformation of $S = e^{-zt}$. In this way, the slope is used as a calculation for total mortality rate

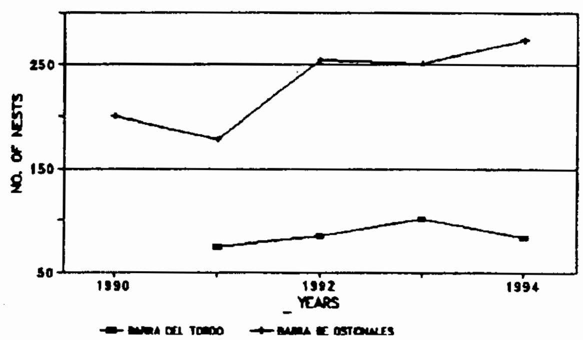

Figure 1. Nesting of Kemp's ridley sea turtles in Ostionales and El Tordo, Tamaulipas. Source: Instituto Nacional de la Pesca.

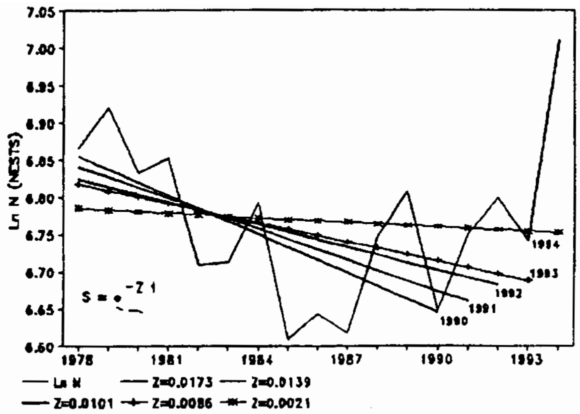

Figure 2. Kemp's ridley nesting trends only in Rancho Nuevo, Mexico. S and Z are survival and total mortality rates. Source: Márquez et al., 1994.

(Z) and annual survivorship (S). Estimates of Z and S are presented by year for the period beginning 1978 in Table 2. Assuming that there is a direct relationship between abundance of nests and abundance of females, these estimates can be used as estimates of mortality and survivorship for nesting females. Table 2 also includes the per cent increase in number of nests for a given year as compared with the number of nests in 1987.

These results indicate that the trend of the estimated total mortality (Z) from all three camps combined was decreasing from Z = 0.0331 in 1987 to Z = -0.0218 in 1994, and for the same period the survival rates (S) were increasing from S = 0.967 to S = 1.022. For the Rancho Nuevo portion only, while there is a negative trend in the number of nests and likely nesting females through the period to 1987, there appears to be a slow, increasing trend from 1987 to the present which is the result of an increase in the observed number of nests (%) added annually (Table 2). If we analyze the change in the number of nests for this part of the beach, the result is that the net increment was 60.58% from the lowest point which occurred in 1985. But if the comparison is made with 1978 data (Table 1), the year when the collaborative efforts between Mexico-USA was started, the increase is only 20.4 %

This slow but steady recovery could be a natural response of the Kemp's ridley populations; however, it is negatively overwhelmed by the high numbers of stranded turtles which occurred in 1994 and 1995 (Steiner, 1994; Teas, 1994, 1995). While there appear to be natural causes for mortality including cold stunning and several human impacts, it appears that the most significant impact for the species survival is the incidental capture by shrimp trawlers throughout the Gulf of Mexico. We

Table 1. Results of the recovery program on the Kemp's ridley sea turtle in the Mexican nesting beach of Rancho Nuevo, Tamaulipas. Eggs and hatchlings are in thousands. Source: Instituto Nacional de la Pesca, Mexico.

Year:	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Nests	6000	5500	5200	4000	3000	2000	1800	1600	1400	1200
Corrals	291	299	117	368	313	172	274	301	277	312
in Situ	300	109	206	125	750	40	149	66	186	53
Boxes	0	0	0	0	0	0	0	0	0	0
Predated	?	27	?	?	?	?	121	128	115	80
Donated	20	20	0	0	0	0	0			
Eggs **	662.8	598.0	549.1	409.6	313.0	208.0	191.5	167.1	155.7	133.8
Hatchlings	29.1	24.1	15.0	28.4	31.4	13.1	14.6	23.5	23.5	11.1
Year:	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Nests	1100	1050	959	1013	927	946	821	823	892	742
Corrals	515	390	834	954	865	897	754	757	798	699
In Situ	56	89	46	23	27	26	13	22	19	4
Boxes	23	0	178	47	38	49	81	23	62	29
Predated	16	57	79	36	35	23	54	44	72	39
Donated	0	0	32	21	30	22	20	20	20	20
Eggs **	117.1	111.6	98.0	103.8	96.4	98.6	85.5	86.3	88.9	76.3
Hatchlings	36.1	30.1	54.0	66.6	49.4	56.0	48.5	39.7	60.0	55.8
Year:	1986	1987	1988	1989	1990	1991	1992	1993	1994	
Nests	768	748	851	902	1011	1129	1375	1229	1545	
Corrals	671	712	831	835	977	1087	1248	1171	1483	
In Situ	16	10	8	17	27	14	8	20	31	
Boxes	23	21	10	25	19	70	49	52	46	
Predated	81	26	12	50	5	13	10	32	15	
Donated	20	20	10	28	25	27	25	3	3	
Smuggling	?	?	?	?	2	15	9	6	16	
Eggs **	75.6	75.9	86.7	93.5	100.2	110.2	123.5	117.6	149.6	
Hatchlings	49.3	46.6	64.7	63.4	76.6	80.5	94.3	84.1	100.8	

* The total number of nests from 1966 to 1977 were evaluated from extrapolations. From 1978 to date is the result of direct counting on the beach (Marquez, 1994). From 1990 to 1994 are included the extra camps.
** The total number of eggs include also those calculated from predation and smuggling.

anxiously await the 1995 nesting data to evaluate the impacts of these factors on the nesting population.

The annual number of Kemp's ridley hatchlings released in Rancho Nuevo has been increasing and we are expecting that the same will occur with recruitment to the nesting population in the future. The increasing range of Kemp's ridley nestings outside of the Rancho Nuevo area, such as Veracruz and Campeche in Mexico and Florida, South Carolina and North Carolina in the USA, is encouraging , but if the high mortality continues, current efforts may not be enough for recovery of this endangered species.

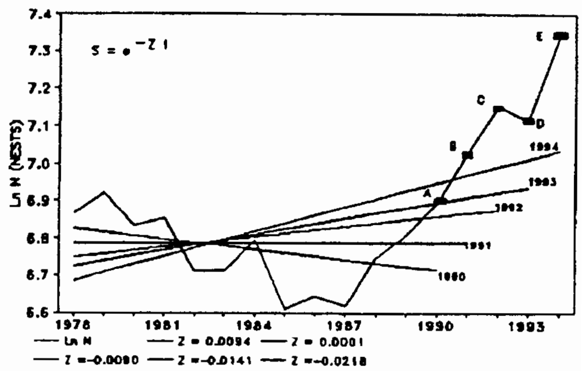

Figure 3. Kemp's ridley nesting trends only in Rancho Nuevo, Mexico. S and Z are survival and toatal mortality rates. A-E includes Ostinales and B-E als Barra del Tordo. Source: Márquez et al., 1994.

Table 2. Total mortality (Z) and survival rate (S) derived from total number of nests laid in the reserve of Rancho Nuevo and the satellite camps. Plus (*) Percent of the number of nests that theoretically were added each year in reference to the lowest point of 1987. Sources: Instituto Nacional de la Pesca, Mexico, Marquez et al. 1994.

Assessment that includes all the camps:								
Year	1987	1988	1989	1990	1991	1992	1993	1994
Z	0.0331	0.0253	0.0174	0.00937	0.00007	-0.009	-0.0141	-0.0218
S	0.967	0.975	0.983	0.991	0.999	1.0091	1.0142	1.022
Sn-S1		0.00762	0.0153	0.0232	0.0325	0.0416	0.0467	0.0546
Nests	719.2	820.8	866	969.6	1098.3	1240.2	1191.0	1511.9
Plus (*)		0.76	2.32	3.25	4.16	4.67	5.46	5.46
Assessment that includes only Rancho Nuevo camp:								
Year	1987	1988	1989	1990	1991	1992	1993	1994
Z	0.0331	0.0253	0.0174	0.0173	0.0139	0.0101	0.0086	0.0021
S	0.967	0.975	0.983	0.983	0.986	0.990	0.992	0.999
Sn-S1		0.00762	0.0153	0.0153	0.0188	0.0225	0.0242	0.0305
Nests	719.2	820.8	866.0	769.8	846.5	901.6	839.1	1154.9
Plus (*)		0.76	1.53	1.53	1.88	2.25	2.42	3.05

Acknowledgments

We would like to thank the Mexican and US fisheries authorities for their continued assistance in this effort, and the supporters in Rancho Nuevo such as Antonio and Juan Gonzalez. We also recognize the support and assistance of students and teachers from the CET del Mar, Universidad del Noreste, Universidad de Tamaulipas, Directior of Fisheries from the Tamaulipas State, Gladys Porter Zoo personnel, the HEART organization of Texas, and countless others for helping us save the species.

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Sea Turtle Excluder Device (TED): A Summary of Technology Transfer to Mexico, 1983-1995

John F. Mitchell[1] and Raúl Villaseñor Talavera[2]

Abstract

Use of the sea turtle excluder device (TED) by the southeastern U.S. shrimp fishery was mandated in 1989 to prevent the incidental capture of endangered and threatened sea turtles. To effectively protect sea turtles throughout their range, the government of Mexico is supporting the adoption of TED technology in its Gulf of Mexico shrimp fleet. Transfer of TED technology from the U.S. to the Mexican shrimp fleet is facilitated through the MEXUS-Gulf cooperative fisheries research program. Fishing gear specialists with National Marine Fisheries Service (NMFS) and the Instituto Nacional de la Pesca (INP) have jointly staged TED workshops throughout the Gulf of Mexico and Pacific coasts of Mexico. In 1992, a joint cruise was conducted in Gulf of Mexico waters off Tamaulipas State to evaluate shrimp catch in nets equipped with, and without TEDs, as well as between two types of TED frames. In 29 tows conducted there were no turtle captures, and no significant statistical difference in the catch rates of shrimp between TED-equipped and non-TED-equipped nets. In 1994, two Mexican TED designs were evaluated by NMFS SCUBA divers using juvenile sea turtles. These evaluations showed the FEDINP design to be effective in excluding small sea turtles. Future collaborative research between NMFS and INP will work toward the development of TED designs and components which will improve turtle exclusion, shrimp retention, and bycatch reduction.

Introduction

As a result of declining populations, sea turtle species which inhabit the southeastern U.S. coastal waters were designated as endangered. These are: Kemp's ridley *(Lepidochelys kempii)*, leatherback *(Dermochelys coriacea)*, hawksbill *(Eretmochelys imbricata)*, and green *(Chelonia mydas)*. The loggerhead (*Caretta caretta*) is designated as threatened. According to Henwood and Stuntz, 1987, data collected between 1977-1984 indicate that an average of 11,179 sea turtles were killed annually by shrimp trawlers operating in southeastern U.S. waters of the Atlantic Ocean and Gulf of Mexico. The National Academy of Science reported in 1990 that shrimp trawling produced the highest number of recorded fatalities in the critical juvenile to adult stage of sea turtles (National Research Council, 1990). In 1977 NMFS, with cooperation from the commercial shrimp industry, began to investigate methods of preventing the incidental capture of sea turtles in shrimp trawls. This research led to the development of the turtle excluder device or TED (Watson and Seidel, 1980). The prototype TED consisted of a rectangular frame with deflector bars slanted at a 45° angle leading to a hinged escape door. The device is installed ahead of the trawl tail bag and forces large objects, such as turtles, out the escape hatch (Figure 1). In 1990, federal regulations were promulgated which mandated TED use by portions of the southeast U.S. shrimp fishery during certain times of the year. In 1992, exemptions to TED requirement expired requiring year-round TED use in all shrimp trawls retrieved with mechanical assistance (U.S. Federal Register, 57(234):57348-57358, December 4, 1992). Since the implementation of TED regulations, the U.S. shrimping industry has assisted in the development of simpler and less expensive TED designs.

Migration patterns of some sea turtle species place them as transients between U.S. and Mexican jurisdictional waters. Most notable among these is the Kemp's ridley which nests along a specific beach area in the Mexican state of Tamaulipas. It is generally believed that as juve-

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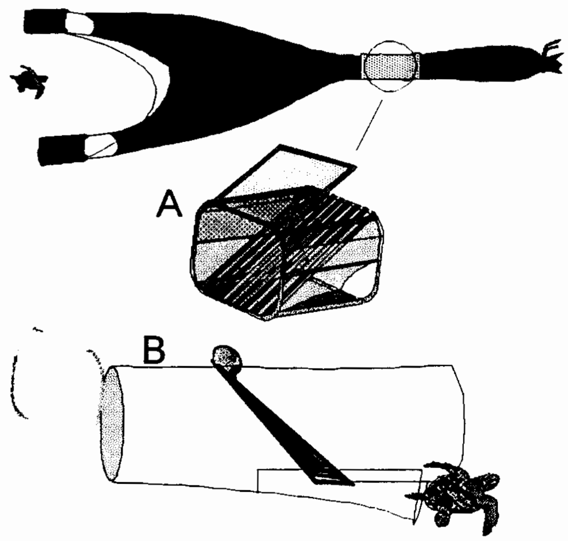

Figure 1. Positioning ofTED in Trawl and two TED designs: A) NMFS TED and B) Bottom Exiting Super Shooter (tm).

niles, the Kemp's ridley becomes a benthic forager in near shore and inshore waters of the U.S. northern Gulf of Mexico. In 1964, the Mexican government initiated "The Integral Program of the Mexican Government for the Protection of Sea Turtles" (Secretaria de Pesca, 1994). In addition to providing for the protection of turtle nesting beaches, the Mexican program supported a systematic research program on the adoption of TED technology and impact of use. This program has been directed by the Instituto Nacional de la Pesca of Mexico (INP). The results from this study led to the establishment of Mexican TED regulations in 1993.

The transfer of TED technology from the U.S. to Mexico is facilitated through the MEXUS-Gulf Cooperative Fisheries Research Program, a technically based forum through which joint fisheries research is conducted. Through MEXUS-Gulf, fishing gear technologists from NMFS and INP work together to: 1) determine optimum TED designs for Mexican fishing conditions and, 2) develop and conduct TED training workshops for INP gear specialists and commercial shrimp fishermen of Mexico.

Methods

Cooperative efforts between NMFS and INP in TED technology transfer to Mexico began in 1983 with a demonstration of the NMFS TED aboard Mexican commercial shrimp trawlers in the Gulf of Mexico and Pacific Ocean. In 1987 NMFS and INP gear specialists conducted comparative trawling of nets equipped with a NMFS TED, Georgia Jumper TED and a webbing panel design called the Morrison soft TED against a standard trawl on the shrimp fishing grounds off Tamaulipas and Sinaloa states. Although tows were limited in number, these early vessel demonstrations indicated little difference in shrimp catch rates between TED-equipped and standard trawls. Further, design features incorporated into the NMFS TED demonstrated an ability to reduce the bycatch of fish in the catch (NMFS Report, 1987).

TED Workshops

Federal certification and subsequent utilization of new TED designs in the U.S. shrimp fishery created a large base of technical and practical information which could be made available to Mexico. In 1990, the first INP-NMFS joint workshop on TED technology was staged in Tampico, Tamaulipas. The format and subject content of this workshop became the prototype for subsequent TED workshops in Mexico and other Latin American nations. Initial workshops provided information on both grid-style TEDs and the soft TED. Due to operational problems and shrimp loss experienced by U.S. fishermen, the soft TED was eliminated from subsequent workshop demonstrations.

A typical TED technology workshop is conducted over a 2-3 day period and is structured in the following manner: 1) classroom instruction, 2) "hands-on" instruction in the construction and assembly of TEDs and, 3) at-sea demonstrations of TED operation aboard a commercial shrimp vessel.

(A) Classroom Presentations

Two to three hours of classroom instruction provide shrimp fishermen and net builders with a generalized introduction to TEDs, leading to more specialized information on TED construction and operation. The following topics are presented: 1) a history of U.S. TED research and development including the concerns and experiences of U.S. shrimp fishermen, 2) videotape programs summarizing TED design options including underwater video of various TEDs at work, 3) presentation of shrimp retention data from U.S. studies (Renaud et al., 1993) and, 4) a discussion of the function of important TED components including troubleshooting information designed to correct problems related to shrimp loss through the TED.

The latter classroom topic presents the results of extensive NMFS and INP research into methods of improving

TED performance (Mitchell et al., 1995). Among the primary methods of preventing shrimp loss through a grid-style TED are: 1) *TED angle*. Through the use of dye injection and current meters, NMFS SCUBA divers have learned that as TED angle decreases, water and shrimp can be diverted out of the turtle escape hole. Maintaining the TED angle at approximately 45° can minimize this type of shrimp loss. 2) *Accelerator Funnels*. The primary function of an accelerator funnel is to direct shrimp away from the turtle escape hole. Funnels are constructed of elastic polyethylene webbing which expands to allow large objects, such as turtles, to pass through the TED and out the escape hole, 3) *Flotation*. TEDs should be sufficiently floated to insure they will not chafe along the sea floor. Bottom-opening TEDs need adequate flotation to insure that debris will be discharged and not accumulate against the TED bars thereby preventing the flow of shrimp to the trawl codend. 4) *Exit hole cover or flap*. U.S. TED regulations allow for the installation of a cover over the turtle exit hole. The cover must meet criteria specified in federal TED regulations. The *extended flap* is designed to be used in combination with a large opening in the trawl extension, facilitating easier exclusion of debris. The flap is constructed of elastic polyethylene webbing permitting large objects to be discharged, then returning to form an effective seal over the escape opening. To further insure the flap maintains closure during fishing operations, it is attached 15.4 cm beyond the posterior edge of the TED frame (Figure 2).

(B) Hands-on instruction

The second component of the workshop provides at least 8 hours of instruction in the construction and installation of a TED into a shrimp trawl. While providing useful information for the shrimp vessel captain, this segment of the workshop is directed toward individuals who will likely be responsible for TED installation and repair, i.e. trawl builders and net repair shops. Participants observe as INP and NMFS TED specialists install a TED and associated components into a trawl extension. Using diagrammatic instructions as a guide, participants are divided into working groups of 4-6 individuals and assemble several TEDs on their own. Through hands-on instruction, the participants obtain a comprehensive understanding of the TED system and its components.

(C) At-Sea Vessel Demonstration

The workshop concludes with a demonstration of TED operation aboard a commercial shrimp trawler. NMFS and INP TED specialists demonstrate the proper methods of rigging a TED for use aboard the vessel, including adjustment of the trawl lazy line. One of the more important aspects of TED deployment and retrieval is the prevention of twists in the trawl netting, just ahead of the TED. If the TED is deployed with a twist, the catch can accumulate ahead of the device during the tow, and be discharged out of the exit hole upon retrieval. In order to prevent twisting, a series of simple modifications to normal deployment and retrieval of the trawl is demonstrated.

Other Cooperative Efforts

TED specialists with NMFS and INP collected data on catch rates of shrimp and bycatch from trawls equipped with two different TED designs aboard a Mexican shrimp trawler in November 1992 (NMFS Report, 1992). Trawling operations were conducted in Mexican waters of the Gulf of Mexico along the northern coast of the state of Tamaulipas. The principal objective of the project was to conduct comparative tows of shrimp trawls equipped with Super Shooter and Anthony Weedless style grid TEDs against non-TED-equipped trawls under conditions typical of the Mexican shrimp fishery. Additionally, the project would identify operational problems with TEDs, specific to the Mexican shrimp fishery.

In 1994, NMFS and INP gear researchers conducted SCUBA diver evaluations of two Mexican TED designs in Panama City, Florida (NMFS TED Test Report, 1994). NMFS divers used underwater video cameras to record the fishing configuration of the Mexican TEDs (Workman et al., 1986). Eight, two year-old captive reared loggerhead sea turtles were introduced into the TED equipped trawls to evaluate their exclusion efficiency.

The Mexican FEDINP TED (Bonilla et al., 1992) is a top-opening hard TED design constructed of 3.8 cm aluminum tubing. The frame is rectangular in shape, with an outside dimension of 129.5 cm x 80.8 cm. The exit hole cover is constructed of 2.6 cm stretched mesh polyethylene webbing extending 60 cm beyond the posterior

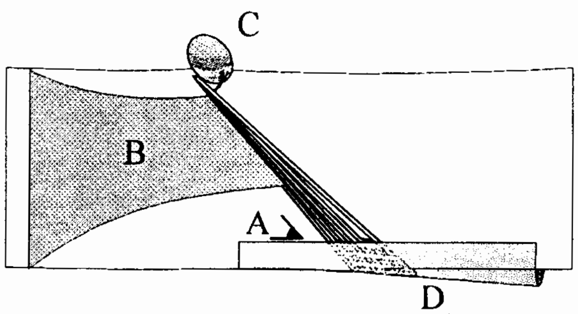

Figure 2. TED components which can improve shrimp retention. A) Maintain TED angle at 45 from horizontal, B) Accelerator funnel, C) Floatation D) Extended Flap.

edge of the TED frame. The INP 3-bag TED features a standard oval grid TED frame with an accelerator funnel incorporated into a modified trawl with three separate codends (Figure 3). Baffles located in the trawl wings separate catch from the center section of the trawl and terminate in separate outside codends. Catch entering the side baffles does not pass through the TED frame. Research conducted by INP has shown that shrimp which transit the trawl along the wings are separated from the flow through the body of the trawl by the side baffles, thereby preventing possible loss through the TED.

Results

Since 1990, NMFS and INP have staged six TED technology transfer workshops among the Gulf of Mexico shrimping ports of Tampico, Campeche and Progreso and four workshops among the Pacific coast ports of Guaymas, Mazatlan and Salina Cruz. These efforts resulted in the training of approximately 28 INP personnel and over 350 Mexican shrimp fishermen in TED technology. INP gear specialists, shrimp fishermen and net builders assembled 83 TEDs during the joint workshops.

Comparative tows conducted off Tamaulipas State in 1992 resulted in the collection of catch data from TED- versus non-TED-equipped trawls during 179 hours of fishing. Shrimp catch per unit effort (CPUE = kg/h) for the Super Shooter TED and corresponding control net was 2.43 and 2.51, respectively, resulting in a difference of 3.4 percent. Shrimp CPUE for the Anthony Weedless TED and corresponding control net was 2.92 and 3.03, respectively, resulting in a difference of 3.6 percent. Differences in the catches of shrimp and bycatch between TED-equipped nets and their corresponding control nets were not statistically significant at the 0.05 level over all phases of the test (Table 1).

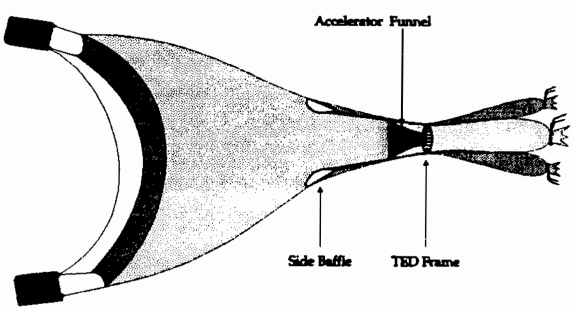

Figure 3. INP 3-bag TED. Source: Instituto Nacional de la Pesca, Mexico.

Table 1. Sample size (n), Observed Mean Difference (CPUE [kg/h] Control -CPUE TED) and Statistical Significance of mean differences for shrimp and bycatch by TED type, averaged over all nets, sides and test phases. (S = significant at 0.05 level, NS = Not significant at 0.05 level). From 1992 joint TED evaluation project, Tamaulipas State, Mexico, National Marine Fisheries Service and Instituto Nacional de la Pesca.

	Weedless TED vs. Control	Super Shooter TED vs. Control
Shrimp:	27 / 3.63 / NS	29 / 2.57 / NS
Bycatch:	26 / 6.01 / NS	29 / 25.5 / NS

Underwater evaluations of the FEDINP TED conducted in 1994 indicated that the device operated a distance of 60 cm from the sea floor at a towing speed of 4.8 m/sec. The operating angle of the frame was measured at 45° from the horizontal. The small mesh exit hole cover sealed the turtle escape opening effectively and appeared to provide virtually no path for shrimp escapement. Of three two-yr-old loggerhead sea turtles exposed to the FEDINP TED, all escaped within a maximum 5 minute exposure period. Evaluation of the INP 3-bag TED resulted in a modification to the side baffle openings. A length of 1.2 cm nylon line was laced to the perimeter of each baffle opening in order to maintain a semi-circular configuration. Of five juvenile turtles exposed to the INP 3-bag TED, two were captured in the side baffles of the net, and thus were not able to escape through the TED. Suggested modifications to this TED design include: installation of a barrier to each of the baffle openings to prevent capture of juvenile sea turtles, and modification of the TED frame to include side hoops that would insure the outer bags remain in an open configuration throughout their length.

As a result of TED technology transfer to Mexico and results obtained by INP during three years of systematic investigation (1991-1994), INP, in coordination with the United Commercial Fishing Organization and the Fisheries Training Program of the Secretaria de Pesca of Mexico, conducted a series of courses and workshops within Mexico for the purpose of training crew members of shrimping vessels in TED technology. The main focus of the workshops was: aspects of the material, construction, installation and operation of the grid style or hard TED. In the Gulf of Mexico and the Caribbean, approximately 400 workshops were conducted, training approximately 2,000 crew members of the shrimp fleet.

Between the months of June-August, 1994, INP conducted 152 TED workshops along the Pacific Coast of Mexico. Each workshop was staged over several days providing each participant with a minimum 20 hours of instruction. During this period, 5,041 fishermen received comprehensive training in TED technology.

Discussion

To effectively protect sea turtles throughout their range, international cooperation is necessary. TED technology workshops conducted by NMFS and INP, working through the MEXUS-Gulf program, have contributed to the conservation of sea turtles in the region by providing fishermen with the information necessary to use TEDs effectively, without adverse loss of shrimp catch.

Future collaborative projects will be directed toward a continuation of joint research and information exchange, as increasing TED use among the fleets of both nations will generate experience and innovation. Additionally, each agency is currently conducting independent research toward the development of technology to reduce the bycatch of important fish species from the commercial shrimp catch. Through MEXUS-Gulf, researchers from both agencies will have an opportunity to exchange information and plan cooperative work toward bycatch reduction technology.

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Stock Assessment Report for the Gulf of Mexico Shrimp Fishery

James M. Nance [1]

Abstract

This stock assessment report deals with the 1960-1994 commercial catch statistics for brown shrimp (*Penaeus aztecus*), white shrimp (*Penaeus setiferus*) and pink shrimp (*Penaeus duorarum*) from the U.S. Gulf of Mexico shrimp fishery. This analysis provides the annual update of the status of the shrimp stocks with regards to catch, effort, catch per unit of effort, average count (number of shrimp per pound), recruitment, number of parents and projected yield.

Introduction

The need to better manage the penaeid shrimp stocks of the United States, to insure that all involved in the fishery may benefit from this common resource, has prompted this research effort. This stock assessment report deals with the 1960-1994 commercial catch statistics for brown shrimp (*Penaeus aztecus*), white shrimp (*Penaeus setiferus*) and pink shrimp (*Penaeus duorarum*) from the U.S. Gulf of Mexico shrimp fishery. This analysis provides the annual update of the status of the shrimp stocks first presented at the Southeast Fisheries Center's Second Stock Assessment Workshop (Nichols, 1984).

Methods

The same procedures explained at length by Nichols (1984) were used in this stock update analysis. The brief synopsis of the methods presented below was taken from a stock assessment report by Nichols (1986). Only minor changes were made to some statements.

Single stocks of brown and white shrimp throughout their ranges in the Gulf of Mexico were assumed during the analysis. A single pink shrimp stock from the Florida Keys to the Mississippi River was assumed. Brown shrimp landings reported in Texas included an unknown quantity of pink shrimp, which was treated as brown shrimp for this analysis. No detailed information was available for shrimp caught and landed in Mexico, so the analyses were conducted as if the ranges of brown and white shrimp stocks ended at the Mexican border.

Computerized 1994 data files for the shrimp landings and effort interviews in the U.S. Gulf of Mexico were obtained from the Research Management Division, Southeast Fisheries Science Center. These data were subjected to the additional editing criteria developed by the Fisheries Analysis Division, Miami Laboratory, as described by Nichols (1984). These edited data were combined with the previously edited 1960-1993 data set for the updated analysis. Estimates of species-directed effort were calculated by the same procedures described by Nance (1992).

No time series data were available for catches not reported through the commercial channels covered by the dealer canvassing program. Although these catches may be sizable, they could not be included in the present analysis. Absence of estimates for unreported catches is probably the greatest potential source of error in this work.

The von Bertalanffy growth curves developed by Parrack (1981) were used as the age-length relationship for brown shrimp. The white shrimp analysis used the seasonally varying growth model developed by Nichols (1981), while growth curves derived by Phares (1981, unpublished) were used for pink shrimp (parameters tabled in Nichols 1984). Necessary length-weight conversions were made using factors reported by Brunenmeister (1980), Parrack (1981), Phares (1980), and Phares (1981, unpublished). Modifications to the t parameters, proceedures to estimate ages of the sexually dimorphic brown and pink shrimp from size data without sex, details of the catch in weight to catch in

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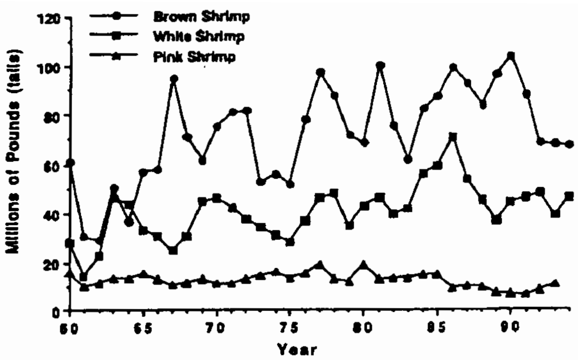

Figure 1. Annual catch data for the Gulf of Mexico shrimp fishery.

numbers by age transformation, and adjustments to the growth relationships for calculating realized yield per recruit remained as described by Nichols (1984).

A natural mortality rate (M) of 0.275 per month for both brown and white shrimp, and 0.30 per month for pink shrimp was used in the present study. Age specific estimates of fishing mortality rates (F) and stock sizes (N) were made using virtual population analysis (VPA). For cohorts considered extinct by December 1993, starting F for the oldest age considered was estimated as F = qf where q took the value associated with each estimate of M (parameters tabled in Nichols, 1984), and f was the directed effort for that month. For cohorts extant in December 1994, age specific estimates of q were calculated as the averages of the F/f ratios for all Decembers preceding 1994. The starting F was then calculated as the product of each q estimate and fishing effort for December 1994. The detailed tables of age specific stock sizes and fishing mortality rates are available from the author.

Number of shrimp by age and month are available from the VPA tables (Nance, 1994). Parent stock is defined for brown shrimp as the number of age 7+ (months) shrimp during the November-February time frame. White shrimp parent stock is defined as the number of age 7+ (months) shrimp during the May-August time frame. Pink shrimp parent stock is defined as the number of 5+ (months) shrimp during the July -June period.

As in Nichols (1984, 1985), deterministic population models were produced for all three species by linking a Ricker-type yield per recruit model to proposed stock recruitment relationships. Recruitment independent of parent stock was also considered, with recruitment set at the geometric mean over the 1960-1994 period. Averages of VPA-derived F estimates for 1992-94 were used as the baseline for current conditions. Yield estimates were made for all three species for a range of "F-multiplier" values from 0-2 (0.02 increments).

Results and Discussion

Catch for the three shrimp species has varied greatly over the past 35-year period (Figure 1). Brown shrimp has had the greatest yield, followed by white shrimp and then pink shrimp. Brown shrimp yield reached an apex in 1990 at 103.4 million pounds, while white shrimp was greatest in 1986 at 70.7 million pounds. Pink shrimp had its greatest catch in 1980 at 19.1 million pounds. Brown shrimp catch has dropped the last three years and was 68.0 million pounds in 1993. White shrimp catch has declined from the maximum over the past seven years and was at 38.8 million pounds in 1993. Pink shrimp dropped dramatically in 1986 and reached a low of 6.1 million pounds in 1991. Pink shrimp catch increased in 1992 with a value of 8.2 million pounds.

Effort has increased steadily from 1960 through 1986 for brown and white shrimp (Figure 2). After 1986, effort values have fluctuated greatly for these two species. Brown shrimp effort is still above the 1986 levels, while white shrimp effort dropped below the 1986 value in 1993. On the other hand, pink shrimp effort has remained quite stable, showing a decrease since 1986 when catch started to decline.

Catch per unit of effort (CPUE; pounds per day fished) is detailed for the three species in Figure 3. Although there are great fluctuations in the data, CPUE has declined slowly for all three species during the past 34 years. Pink shrimp has increased the three years since reaching its lowest value of 346 pounds per fishing day

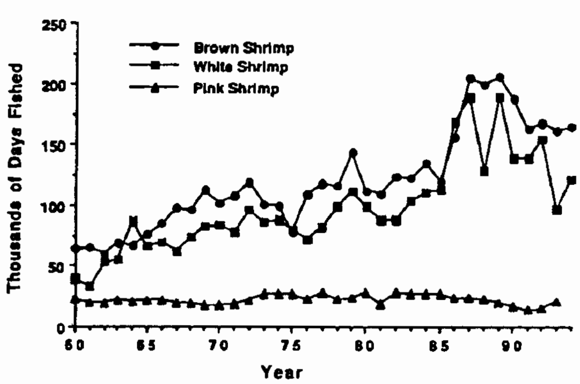

Figure 2. Annual effort data for the Gulf of Mexico shrimp fishery.

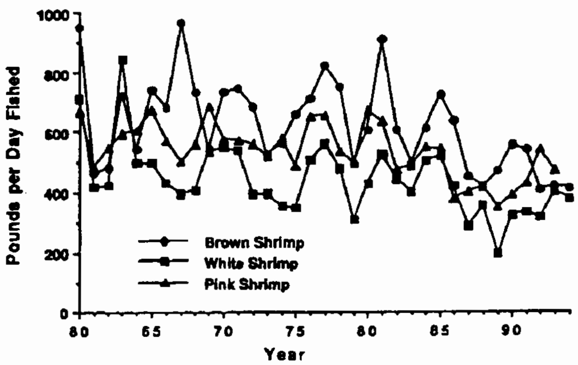

Figure 3. Annual CPUE data for the Gulf of Mexico shrimp fishery.

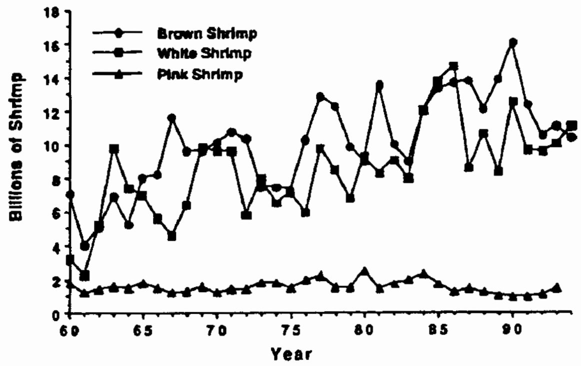

Figure 5. Annual recruitment data for the Gulf of Mexico shrimp fishery.

in 1989. Brown and white shrimp CPUE values were both around 400 pounds per fishing day in 1993. White shrimp CPUE is up from a low of 192 pounds per fishing day experienced in 1989, while brown shrimp CPUE is down slightly from values of around 550 pounds per fishing day in 1990 and 1991.

Average count (number of shrimp per pound) is examined for the three species in Figure 4. Pink shrimp have usually had the largest (smallest count) shrimp landed. Pink shrimp have had fluctuations in the size of shrimp landed, but over the past few years these fluctuations have occurred around a central point of about 55 count. In 1992 the average pink shrimp was at 53 count. White and brown shrimp have increased in count over the past 34-year period. Average size of white shrimp landed in 1993 was 72 count, while it was 86 count for brown shrimp.

Recruitment for brown shrimp showed a steady increase from 1960 until 1990 (Figure 5). Brown shrimp recruitment has dropped the last three years. The recruitment of white shrimp reached a peak in 1986 and has shown a fluctuating decline since that time. Pink shrimp recruitment showed a great decline in 1986 and has been near this low level since. A slight increase in recruitment was noted in 1992.

The estimated numbers of parents during a given monthly period are presented in Figure 6. White shrimp had lowest parent numbers in the early 1960s, while the lowest brown shrimp parent numbers were found during 1983. Pink shrimp had lowest parent number in 1990, but has shown an increase during the last two years.

Yield curves provide us with choices about how to best manage the fishery (Figure 7). Each of the curves show that at the current effort levels (F-multiplier = 1.0) yield is at the maximum (i.e., the stock is fully exploited for each species). No increase in effort will produce an increase in yield.

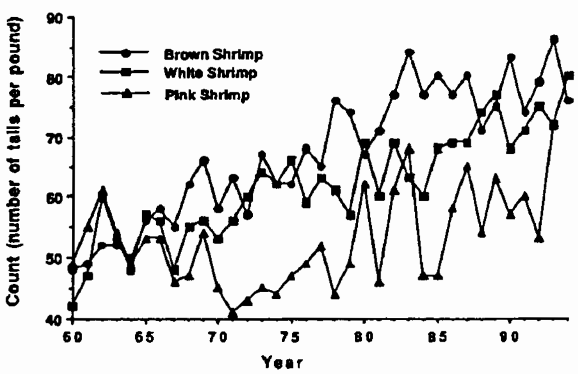

Figure 4. Annual size data for the Gulf of Mexico shrimp fishery.

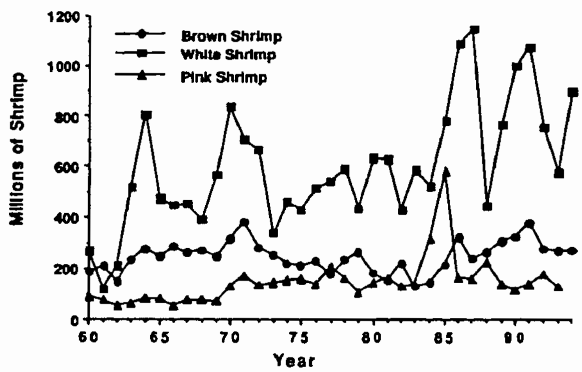

Figure 6. Annual parent data for the Gulf of Mexico shrimp fishery.

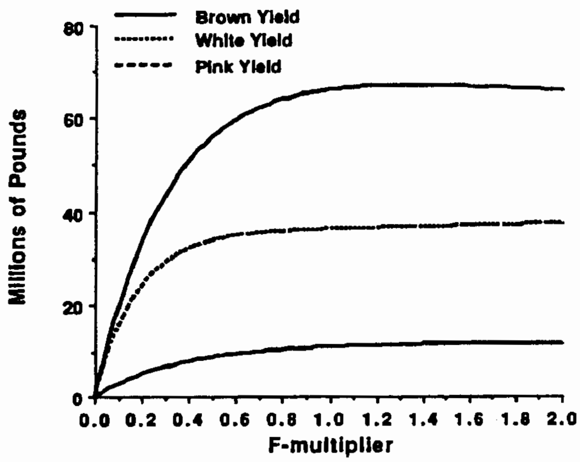

Figure 7. Annual yield data for the Gulf of Mexico shrimp fishery.

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Phytoplankton Biomass, Zooplankton, and Larval Fish Assemblages Associated with the Yucatan Upwelling Area

Andrew W. David[1], Churchill B. Grimes,[1] Thomas D. Leming,[2] Guillermo Ortuno,[3] and Aurora Monreal[4]

Abstract

The persistent upwelling area generated by the Yucatan Current sweeping up the continental shelf off Isla Mujeres and over the Campeche Bank creates an increased abundance of forage which should aid growth and survival of larval and juvenile fishes, and boost recruitment to the fishery resources in southeastern Mexico. Federal scientists from the U.S. (NMFS) and Mexico (INP) conducted a detailed ichthyoplankton survey of this area in January-February 1990. Satellite imagery revealed a plume of cool water (2.0-2.5°C below surrounding waters) 10-15 km wide by 45 km long generally running SE to NW. Real-time radio telemetry of satellite imagery data to the research vessel allowed five survey tracks to be chosen on-site for optimal coverage of the upwelling area. Macrozooplankton and phytoplankton (by chlorophyll a) were collected along with hydrographic vertical profiles. Ichthyoplankton was collected with 1 x 2-m neuston (mesh = 957 μm) and 60-cm bongo (mesh = 333 μm) nets. Chlorophyll a and macrozooplankton were strongly negatively correlated with SST, $r = -0.85$ and $r = -0.41$, respectively. Ten families, including the economically important scombrids, carangids, and mugilids, comprised 75.6% of ichthyoplankton collected, of which 60% were pelagic species and 40% demersal species. Chlorophyll a, macrozooplankton, and ichthyoplankton peaks were sequentially shifted downcurrent (NNW) from the most intense upwelling area.

Introduction

The rich fishing grounds of the Campeche Bank provide large catches of grouper, snapper, grunts, porgies, and lobster, but very little fishery research has been conducted in this area (Sanchez-Velasco and Flores-Coto, 1994; Richards et al., 1993; Rodriguez-Capetillo et al., 1997) (Figure 1). In January and February 1990 NMFS and INP conducted a joint ichthyoplankton survey of the Yucatan coast of the Gulf of Mexico. The objectives of this cruise were threefold, (1) to collect in situ and remotely sensed environmental data in the Yucatan upwelling area, (2) to determine the distribution and abundance of phytoplankton, zooplankton, and larval fish assemblages, and (3) evaluate the potential effect on recruitment to the valuable Campeche Bank fishing grounds.

The upwelling is created when the Yucatan Current collides with the eastern escarpment of the Campeche Bank. Several authors have examined the physical oceanography of the area examined in this study (Hamilton, 1991; Lewis et al., 1991; Monreal-Gomez and Salas-de Leon, 1990; Molinari and Morrison, 1988). The current flows up from the 2,000 m depths of Yucatan Channel and over the bank bringing cold nutrient-rich water to the surface triggering a proliferation of marine life exceeding that found in adjacent waters. The Campeche Bank is roughly 600 km wide and extends approximately 250 km offshore. This carbonate platform remains relatively shallow as depths of 100 m are common 180 km offshore. Contrasting this is the very narrow shelf on the eastern side of the peninsula where depths exceeding 200 m are common just a few kilometers off the beach. This upwelling is persistent throughout the year although

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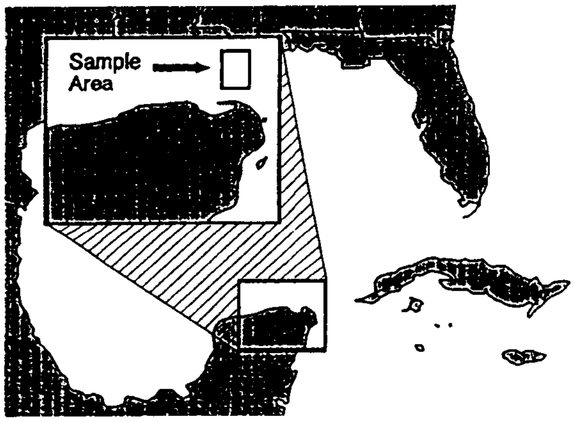

Figure 1. Sampling area.

there is some variation in the location of the surface temperature minimum due to shifts in the prevailing wind direction.

Samples were collected at 49 stations during 4 days in February of 1990. The sampling area was 74 km along the north-south axis and 93 km along the east-west axis. Four transects of ten stations were run beginning in the southeast and proceeding northwestward, a fifth transect was also surveyed on the eastern edge of the Campeche Bank where nine stations were surveyed. The transects were 18 km apart and the stations were 7.5 km apart within the transects. Real time satellite imagery of sea surface temperature was used to select the survey transects and to confirm the seasonal persistence of the upwelling. Hydrographic and phytoplankton data were collected with a CTD and Niskin bottle array. Zooplankton and ichthyoplankton were collected with 60 cm bongo nets with 333 μm mesh and 1.0 x 2.0 m neuston nets with 947 μm mesh. All net catches were preserved in ethanol.

There was a 3°C depression in the surface temperature in the center of the southern half of the survey area where cold upwelling water of the Yucatan Current reached the surface. In addition to the thermal differences, the water in the upwelling area was noticeably green in contrast to the clear blue water of the nearby Caribbean. The spatial displacement of the surface temperature minimum from the edge of the shelf reflects the high velocity of the Yucatan Current which can be as high as 2.5 meters per second. Phytoplankton concentration, based upon chlorophyll a values, showed a very strong negative correlation to surface temperature with an r value of -0.85. The surrounding Caribbean water had much lower values of chlorophyll a, typically less than 0.15 $\mu g \cdot l^{-1}$ compared to levels of nearly 2.00 $\mu g \cdot l^{-1}$ in the upwelling area. The phytoplankton maximum was approximately 50 km downcurrent from the maximum upwelling. Zooplankton concentrations were elevated in the southwest of the upwelling, displaced slightly downcurrent from the phytoplankton maximum. Zooplankton values were determined by settlement volumes taken from the bongo nets. As with chlorophyll a, there was a strong negative correlation with sea-surface temperature although the relationship, with a value of -0.41, was not as strong as with chlorophyll a.

Not surprisingly, larval fish responded to the enriched nutrients, phytoplankton, and zooplankton. The bongo-collected ichthyoplankton maximum was shifted farther downcurrent still from the zooplankton maximum and about 67 kilometers from the maximum upwelling. There were 4,809 fish collected with the bongos. The neuston ichthyoplankton collections displayed a prominent peak in the southwest corner with a smaller peak farther north along the western boundary of the sampling area (Figure 2). There were over 6,300 fish collected with the neuston nets representing at least 43 families. The ten most abundant families accounted for 77% of the total fish collected. These ten families in descending order of abundance were: Exocoetidae (1,220), Carangidae (761), Atherinidae (584), Mugilidae (430), Clupeidae (396), Scombridae (283), Sparidae (267), Blenniidae (167), and Gerriidae (139). Four of these families were generally at their maximum in the southwest, the Blenniidae, Carangidae, Sparidae, and Clupeidae; three families, the mullids, scombrids, and mugilids had maximum densities along the central and northwestern stations; and three families had more random distributions that were not easily categorized, the most abundant family, the Exocoetidae, as well as the atherinids and the gerriids. There was a good mixture of pelagic families

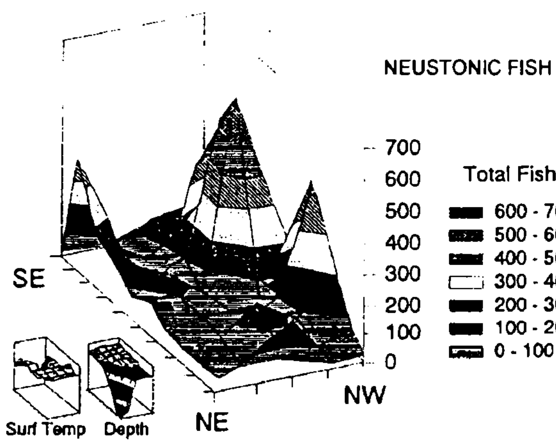

Figure 2. Distribution of larval and juvenile fish.

km wide and 45 km long along a northwest-southeast axis, (3) the maximum surface chlorophyll a readings were strongly associated with the surface temperature minimum, (4) the macrozooplankton maximum was shifted slightly downcurrent from the chlorophyll a maximum, and (5) the ichthyoplankton peaks were shifted slightly downcurrent from the zooplankton and somewhat farther from the chlorophyll a maximum.

The Yucatan Current impacts the continental shelf off Isla Mujeres which forces cold nutrient-rich water up from over 1,500 meters onto the 35-55 meter deep Campeche Bank. This persistent influx of nutrients from the upwelling, augmented with coastal upwelling due to Ekman transport, drives increases in phytoplankton, zooplankton, and ichthyoplankton on the Campeche Bank as the current flows westward. The increases in prey types and amounts which are available due to the upwelling-supplied nutrients are likely to increase the recruitment success of all fishes including commercially growth and decreased larval stage duration over larvae in the surrounding nutrient poor waters. It is also possible that larger ecosystem scale benefits are imparted to the Campeche Bank by this upwelling feature in that

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Mark-Recapture Research on King Mackerel, *Scomberomorus cavalla*, in the Gulf of Mexico

William A. Fable, Jr.,[1] Karen M. Burns,[2] and Francisco Solis Celada[3]

Abstract

Over 6,900 king mackerel were tagged with internal anchor tags between 1983 and 1989 from northwest Florida westward and southward through the Gulf of Mexico to waters off the Yucatan Peninsula of Mexico. Three hundred and ninety-two tags were recovered. Previous studies indicated that king mackerel from south Florida waters moved into and across the northern Gulf in spring and summer, and returned in the fall to wintering grounds in south Florida. Other studies presented evidence for two or more migratory groups of king mackerel in the Gulf of Mexico. The present report provides convincing evidence for a migratory group in the western Gulf which seasonally moves between U.S. waters in the north and Mexican waters in south, and is exploited in both countries.

Introduction

The king mackerel, *Scomberomorus cavalla*, is a coastal pelagic scombrid that ranges from Cape Cod to Brazil in the western Atlantic Ocean. In the Gulf of Mexico, this species supports important commercial and recreational fisheries in the United States as well as commercial fisheries in Mexican coastal waters. In U.S. waters, king mackerel are regulated by fishery management plans which impose catch quotas and daily bag limits. No regulations exist in Mexican waters.

Results of previous mark-recapture studies on king mackerel in the Gulf have been published by several authors. Williams and Godcharles (1984) discussed movements of fish tagged in the Gulf off southwest Florida, Texas and Veracruz, Mexico between 1976 and 1979. Vasconcelos (1987) reported on king and Spanish mackerel migrations along the Mexican Gulf coast. Work by Sutter et al. (1991) was a more recent analysis of the tagging study conducted in the 1970s by Williams and Godcharles.

Results from these mark-recapture studies show a generalized pattern of king mackerel movements in the Gulf. In spring, fish migrate northward from wintering grounds off south and southwest Florida (Figure 1). By late summer they occur throughout the northern Gulf (Figure 2).

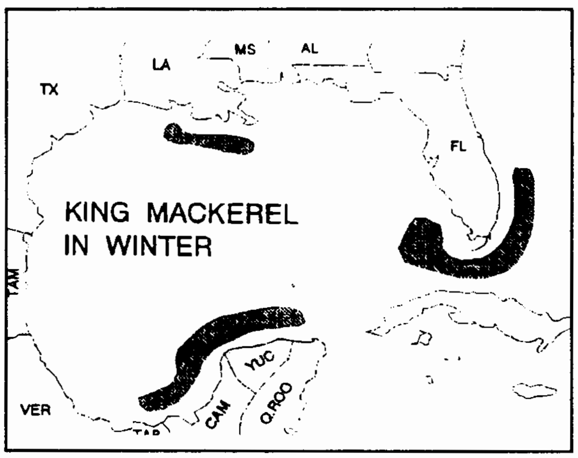

Figure 1. Winter distribution of king mackerel.

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As winter approaches, these fish again return to southern Florida; but there are indications that some winter off Mexico. Data also indicate that many larger king mackerel reside year round in the northwestern Gulf.

Methods

As part of MEXUS-Gulf cooperative research, king mackerel were tagged in U.S. waters off northwest Florida, southeast Louisiana, and Texas and in Mexican waters off Tamaulipas, Veracruz, and the Yucatan Peninsula (Figure 3). Over the years, numerous organizations participated in the tagging effort. They include the National Marine Fisheries Service, the Instituto Nacional de la Pesca, Mote Marine Laboratory, the Texas Parks and Wildlife Department (TPWD), Louisiana State University (LSU), and the Louisiana Department of Wildlife and Fisheries (LDWF).

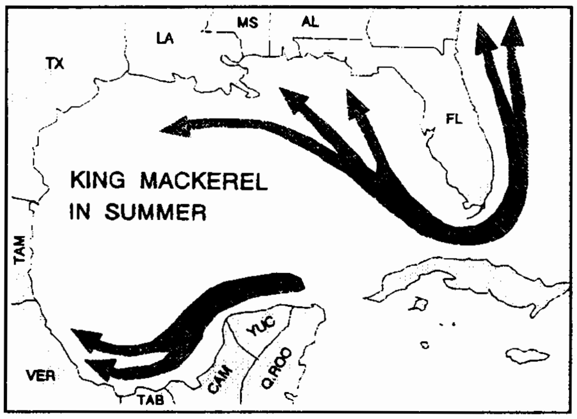

Figure 2. Summer distribution of king mackerel.

Briefly, we used internal anchor tags which had a retainer 32 mm long and 8 mm wide, and a streamer 89 mm long. All tags were either bright red or international orange and had an identification number and return address printed on them. Rewards of $10 per tag return were offered and in recent years, to combat poor returns rates in the U.S., a yearly $1,000 drawing was initiated for U.S. returned tags. In all areas, posters and other means of informing the public (especially newspaper and magazine articles) were used to advertise the tagging program and the rewards.

King mackerel to be tagged were taken by the most effective method available in each tagging area. Usually, this involved catching the fish by hook and line, either off private or government-owned boats, or off commercial handline vessels. However, off Veracruz, many king mackerel were taken using commercial trap nets (almadrabas); this method was quite productive when these nets were available. After the king mackerel were unhooked or removed from the trap net, they were placed belly-up in a V-shaped tagging cradle and their fork lengths were measured. A small slit (8-10 mm long) was made in the abdomen with a scalpel and the disk portion of the internal anchor tag was inserted. The fish was then released into the water.

From January 1983 through December 1989, 6,910 king mackerel were tagged in the Gulf (Table 1). Fish were tagged during every month of the year with the greatest numbers tagged in May (over 1,400) off Veracruz and in December (over 1,100) off Louisiana. Three-hundred ninety-two tags were recovered: 158 from fish tagged off the states of Tamaulipas and Veracruz, 4 from fish tagged off the Yucatan Peninsula, 111 from fish tagged off northwest Florida, 76 from fish tagged off Louisiana, and 43 from fish tagged off Texas. The overall return rate was 5.7%.

Northwest Florida Results

Sixteen hundred and fifty-six king mackerel were tagged off Panama City, northwest Florida, by the NMFS during the months of May through October from 1983 through 1988. We used small government outboard boats and the fishing was relatively close to shore. In general, these fish were smaller than any others tagged in the northern Gulf. There were 111 recovered tags, (a return rate of 6.7%).

Fish tagged off northwest Florida were recaptured dur-

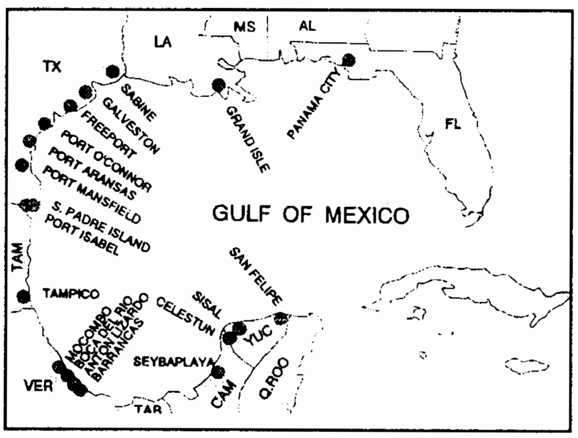

Figure 3. Tagging locations in the Gulf of Mexico.

Table 1. King mackerel tag recoveries by area and year.

Year		Northwest Florida	Louisiana	Texas	Tamaulipas/ Veracruz	Yucatan Peninsula	Combined
1983	Tagged	69	1,409	0	0	0	1,478
	Recovered	10 (14%)	40 (3%)	0	0	0	50 (3%)
1984	Tagged	147	44	0	18	0	209
	Recovered	8 (5%)	5 (11%)	0	0 (0%)	0	13 (6%)
1985	Tagged	6	515	100	369	0	990
	Recovered	1 (17%)	24 (5%)	3 (3%)	11 (3%)	0	39 (4%)
1986	Tagged	556	0	63	175	118	912
	Recovered	21 (4%)	0	6 (10%)	7 (4%)	2 (2%)	36 (4%)
1987	Tagged	402	430	178	461	13	1,484
	Recovered	21 (5%)	7 (2%)	12 (7%)	28 (6%)	0 (0%)	68 (5%)
1988	Tagged	476	0	253	524	17	1,270
	Recovered	50 (11%)	0	20 (8%)	75 (14%)	2 (12%)	147 (12%)
1989	Tagged	0	0	21	530	16	567
	Recovered	0	0	2 (10%)	37 (7%)	0 (0%)	39 (7%)
Total	Tagged	1,656	2,398	615	2,077	164	6,910
	Recovered	111 (7%)	76 (3%)	43 (7%)	158 (8%)	4 (2%)	392 (6%)

ing every month of the year except November. Most (57, or 51%) were recovered in the summer months from the northern Gulf between Sarasota, Florida and Port Aransas, Texas, but one was returned from Veracruz, Mexico. During the winter months, 19 tags were recovered (17% of the total); all but two were from south, southwest or southeast Florida. Of the two others, one was recaptured off Campeche, Mexico, while the other was recaptured off Grand Isle, Louisiana. Recoveries of 35 tags (32% of the total) in spring and fall were spread between the northern Gulf and south and southeast Florida.

Sutherland and Fable (1980) deduced from tagging off northwest Florida that an annual migration occurred from south Florida to the northern Gulf of Mexico in the spring and that these fish returned to south Florida in the fall. We had no direct evidence that king mackerel tagged off northwest Florida ever moved farther west. We now know of 16 tag recoveries reported from the northern Gulf, west of the state of Florida. Also two tag recoveries from Mexico, one from Veracruz and one from Campeche, were reported.

Most northwest Florida fish appear to winter off south Florida, but as they get older and larger, they migrate farther west in the northern Gulf in their summer grounds. Some of these fish may recruit to a year-round resident stock off Louisiana, as evidenced by one winter tag return off Louisiana. A small percentage of the fish tagged in northwest Florida may actually belong to a western Gulf group of king mackerel and be near the eastern edge of their range at the time of tagging, as evidenced by two tag recoveries from Mexico.

Louisiana

When a commercial handline fishery for king mackerel developed in the early 1980s off Grand Isle, Louisiana, we saw an opportunity to acquire king mackerel for tagging in that area. We fished off small commercial trolling boats and small government boats and NMFS biologists worked with scientists from Louisiana State University and the Louisiana Department of Wildlife and Fisheries.

Off Grand Isle, Louisiana, we tagged 2,398 fish and 76 tags were recovered (a 3.2% return rate). Fish tagged during winter (November through April) (1,853) were generally large with fork lengths (FL) averaging 967 mm, while fish tagged during summer (May through October) (545) had a mean FL of only 805. The tagged king mackerel from Louisiana were recaptured during every month of the year, and were taken in the tagging area during every season. Twenty-six recoveries (34%) were made in winter months with 16 tags returned from Louisiana, 8 from south Florida, 1 from Veracruz and 1 from Campeche. Twenty-nine recoveries (38%) were made during the summer, with all recaptures coming from Texas and Louisiana waters. The 12 fall recoveries and 7 of the 9 spring recoveries also all came from off Texas and Louisiana. Two remaining spring recaptures were from Veracruz.

King mackerel tagged in winter exhibited different movement patterns from those tagged in summer. Winter fish tended to move less distance than summer fish. If winter tagged fish showed any movement at all, it was to the west. Summer tagged fish moved in both directions, with 8 (42%) moving east, 4 (21%) moving west, and 7 (37%) showing no movement.

In 1987 we concluded that there is a year-round resident population of large king mackerel in the northwest Gulf (Fable et al., 1987). The 21 new tag recoveries reported from MEXUS-Gulf tagging support that conclusion. However, two additional tag recoveries from the state of Veracruz from fish tagged in September and November off Louisiana, indicate that migrations to Mexican waters may be more commonplace than previously thought.

Texas

In Texas, 43 tags were recovered from 615 tagged king mackerel (7.0% recovery rate). All fish were tagged from May through September by TPWD biologists and sportsmen. Length-frequency distributions of all tagged fish off Texas indicate a wide range of sizes tagged each year.

The only recoveries in Texas waters occurred in summer. Three other recoveries were made in the summer, one off western Louisiana, and two off Mexico. In the winter months, the only recoveries from fish tagged off Texas were in Mexican waters (Veracruz, Campeche, and Yucatan) and in southern Florida. Four recoveries in Mexico (three in Veracruz, one in Campeche) and one in northwest Florida occurred during spring. During the fall, three tags were recovered in Mexico, six in the northern Gulf, and one in south Florida.

King mackerel tagging in the 1970s verified that migrations between south Florida in winter and the Texas coast in summer were common. More recent tagging indicates that migrations to Mexican waters may be even more common (15 recoveries in Mexico versus 11 in Florida). This is consistent with electrophoretic evidence found by Dr. Allyn Johnson in which the Texas coast is shown to be a mixing area between fish from both the eastern and western Gulf. Although no winter tag returns came from Louisiana, we believe that some Texas fish also enter the group of year-round residents off Louisiana.

Tamaulipas and Veracruz

In Mexico, the cooperative efforts of the Instituto Nacional de la Pesca (INP), Mote Marine Laboratory and the NMFS enabled us to tag 2,077 king mackerel in the states of Tamaulipas and Veracruz. Were it not for the publicity and development of an effective reward system, the 158 recovered tags would never have materialized.

An intense commercial fishery in the spring off Veracruz provided an excellent means of acquiring fish for tagging. The almadrabas which were used for several seasons enabled us to simply pick fish out of the net while it was being tended and tag them. The other method used in this area was to troll from INP skiffs or go out with the handline fishermen to acquire fish for tagging.

King mackerel tagged off Tamaulipas and Veracruz were mostly recovered in May (63) and June (37). In spring, especially May, 80 of 81 tags recovered from this tagging were recovered off Veracruz in the commercial fishery. In summer, 51 of 60 tags were recovered off Veracruz while the other 9 tags were taken off Texas (5), Tamaulipas (2), Louisiana (1), and Campeche (1). Seven tags were returned in the fall, from Veracruz (5), Yucatan (1) and Texas (1), while 10 tags (Campeche (4), Veracruz (3), and Yucatan (3)) were recovered during the winter at the southern extent of the range of these fish.

Yucatan Peninsula

The handline fishery is not found off the Yucatan Peninsula. In this area, gillnets were the fishing gear primarily used for king mackerel. The fish that were tagged here were tagged by INP and Mote Marine Lab biologists from research vessels.

Off the Yucatan Peninsula, including the states of Quintana Roo, Yucatan, and Campeche, 164 king mackerel were tagged. All fish were tagged in the months of January through April and 4 tags were recovered.

Of the three king mackerel recovered from tagging off Yucatan, only one was recovered outside of that state. This tag was recovered in summer off Veracruz. The one tag recovered from tagging off Campeche was recovered in Yucatan over two years later.

In summary, the MEXUS-Gulf king mackerel tagging over these seven years added greatly to our knowledge of king mackerel movements in the Gulf. Although we had indications of international movements of king mackerel, this tagging showed that these movements are commonplace and when this information is combined with genetic data based on electrophoretic studies, it is apparent that at least two stocks are present in the Gulf of Mexico, with the western stock making annual migrations into U.S. waters, and being exploited by both nations.

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Temporal and Spatial Variation in Growth and Age/Size Structure of the Fisheries for King Mackerel in the Gulf Of Mexico

Douglas A. DeVries,[1] Churchill B. Grimes,[1] and Francisco Solis Celada[2]

Abstract

We aged 4,038 king mackerel, *Scomberomorus cavalla,* from the eastern Gulf of Mexico and 2,652 fish from the western Gulf collected during 1986-1992 from Florida to Yucatan, Mexico, using sagittae. Length data were also collected on approximately 15,700 eastern and 19,800 western Gulf fish during 1986-1989. The overall age distributions for all age samples were quite similar between sexes within areas and within sexes between areas. The maximum ages and sizes of king mackerel from the eastern and western Gulf, respectively, were 22 and 23 yr and 127 and 117 cm for males and 21 and 24 yr and 158 and 147 cm for females. Growth was significantly different ($p < 0.01$) between sexes within regions and between regions within sexes. Mexican age samples were dominated by 1-3 yr olds compared to 1-8 yr olds in the U.S. western Gulf. Modal size of Mexican fish caught by commercial hook-and-line was 70-80 cm vs. 90 cm for west Gulf fish from Louisiana.

Introduction

King mackerel, *Scomberomorus cavalla,* are highly sought after by U.S. recreational and commercial fishermen from North Carolina to Texas (Manooch, 1979), and they support a substantial commercial fishery in Mexico as well (Gulf of Mexico and South Atlantic Fishery Management Councils, 1991).[3] The species is managed as two stocks or migratory groups, an Atlantic and a Gulf, although the Councils recognize that there are actually two groups-an east and a west-in the Gulf (Gulf of Mexico and South Atlantic Fishery Management Councils, 1990; Johnson et al., 1994).[4]

The life history and characteristics of the fisheries of king mackerel have been well studied (Beaumariage, 1973; Johnson et al., 1983; Trent et al., 1983; Manooch et al., 1987; Trent et al., 1987; Collins et al., 1989; Sturm et al., 1990). Except for the latter two studies, the usefulness of this information for current stock assessments is limited for several reasons.

Much of the work was based on data collected 15 to 25 years ago when exploitation rates and population size were certainly different; some studies were geographically limited; and all studies involving ageing relied solely on whole otoliths, which results in considerable under-ageing of older, larger fish (Collins et al., 1989).

One objective of this study was to compare the age and growth of king mackerel from the eastern and western Gulf of Mexico collected during 1986-1992. A second objective was to compare the age and growth of king mackerel from Mexican and U.S. waters in the western Gulf and to compare size distributions of commercial hook-and-line fisheries in those two areas.

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Methods

King mackerel were collected during 1986-1992 as part of a cooperative Mexican, state, and NMFS program designed to provide the age and length-frequency data needed to conduct stock assessments. For ageing data, we used stratified sampling to collect sagittal otoliths by year, region (E. and W. Gulf), sex, and 10-cm size interval, with a goal of 20 fish per stratum. The regions, which reflect current hypotheses on stock boundaries (Johnson et al., 1994; Gulf of Mexico and South Atlantic Fishery Management Councils, 1990[4]) were defined as 1) Eastern Gulf: Florida Keys through Mississippi, and, during April-October, Louisiana; and 2) Western Gulf: Mexico, Texas, and, during November-March, Louisiana. For most of the length frequency data, samplers attempted to collect, from fish selected randomly, fork lengths on at least 200 fish (and sex data whenever possible) each month from each type of gear during the fishing season. All fish were measured to the nearest centimeter fork length (FL) and all references to length herein are in those units.

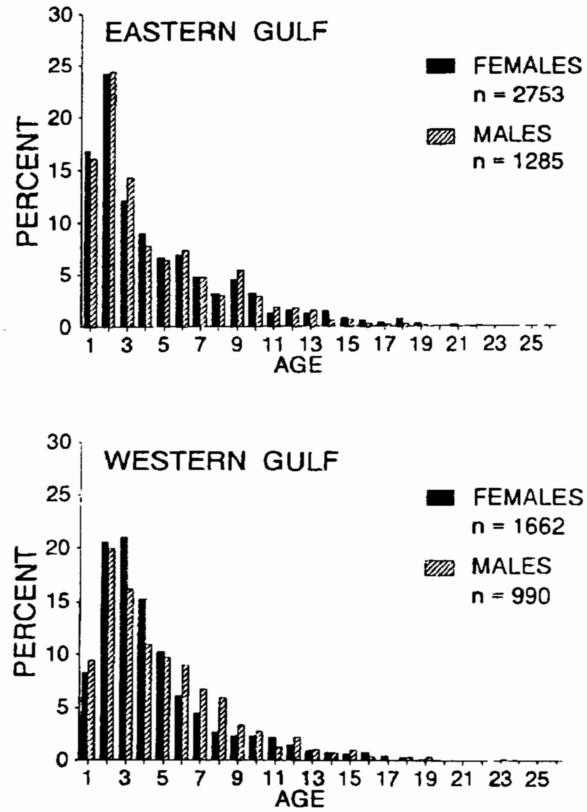

Figure 1. Overall age distributions by sex of king mackerel ageing samples collected during 1986-1992 from the eastern and western Gulf of Mexico.

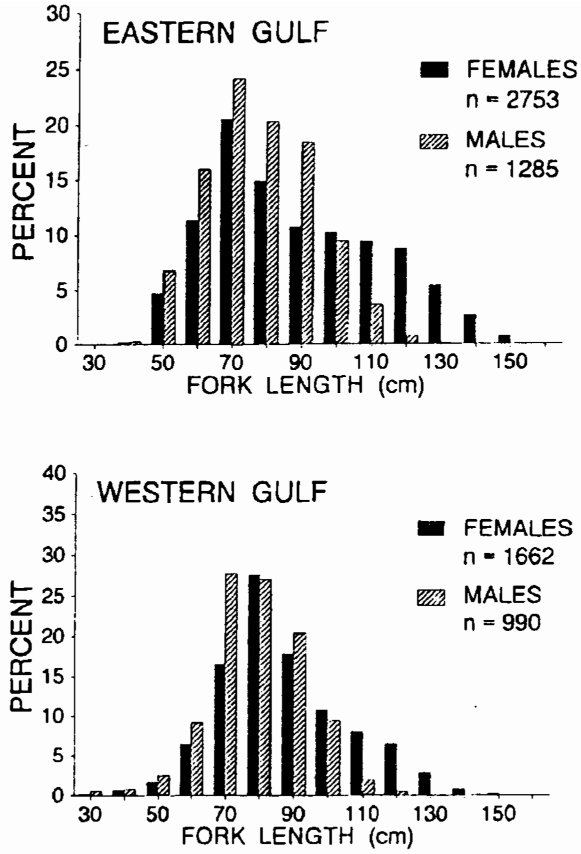

Figure 2. Overall size distributions by sex of king mackerel ageing samples collected during 1986 - 1992 from the eastern and western Gulf of Mexico.

Otoliths from males < 80 cm and females < 90 cm were read whole, while larger fish were aged using transverse sections of the otoliths.

Von Bertalanffy growth equations were fitted to quarterly observed lengths-at-age using Marquardt's nonlinear regression procedure (SAS Institute, Inc., 1988). We tested for differences in von Bertalanffy equations using an F statistic derived from the multivariate Hotelling's T^2 (Bernard, 1981; Vaughan and Helser, 1990).

Unsexed length frequency data were sexed using sex ratios generated from sexed length data collected in the same year, region, and 5-cm size interval. Age composition was estimated by ageing length frequency data using age data from the same year, region, sex, and 5-cm size interval.

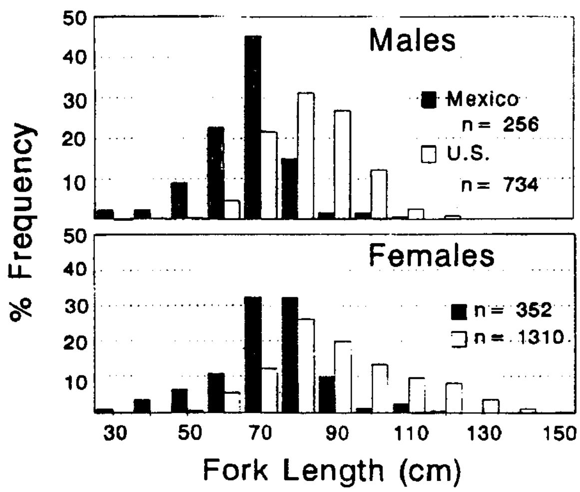

Figure 3. Overall size distributions of male and female king mackerel ageing samples collected during 1986 - 1992 in Mexican and U.S. waters of the western Gulf of Mexico.

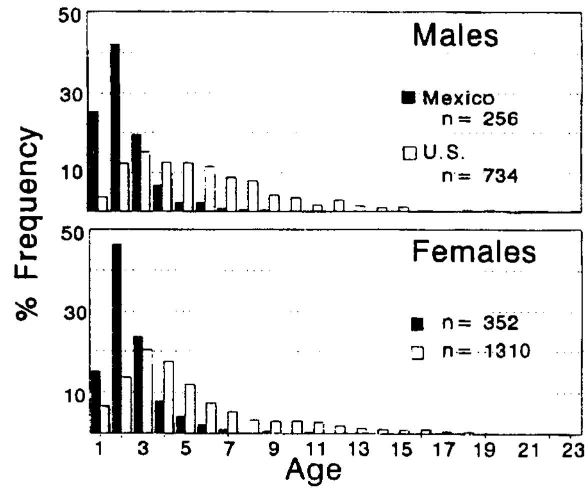

Figure 4. Overall age distributions of male and female king mackerel ageing samples collected during 1986 - 1992 in Mexican and U.S. waters of the western Gulf of Mexico.

Results and Discussion

The age distributions of male and female king mackerel in our ageing samples were very similar both within and between the east and west Gulf regions (Figure 1). The oldest males were 22 yr (110 cm) and 23 yr (101 cm) and the oldest females were 21 yr (127-150 cm) and 24 yr (144 cm) in the east and west Gulf, respectively. In both regions 99% of males were < 16 yr old, while 99% of females were < 18 yr in the east and < 17 yr in the west Gulf.

Maximum sizes were quite different between sexes, but within sexes, were similar between regions (Figure 2). Females grew much larger than males in both regions-158 cm versus 127 cm in the east Gulf and 147 vs 117 cm in the west Gulf. As one can see, the between-region differences within sexes are quite small. We realize that these are not random samples, and therefore do not represent the population distributions, but they do provide good estimates of typical maximum ages and sizes.

Within the west Gulf, males in the Mexican ageing samples were dominated by 70-cm fish with very few > 80 cm, while the mode of U.S. samples was 80 cm with many individuals to 100 cm (Figure 3). The size modes of females were not very different-70-80 cm in Mexican vs. 80 cm in U.S. waters, although the proportion of larger fish was much higher in the latter. The largest female and male from Mexico were 122 and 109 cm compared to 147 and 117 cm from the U.S.

The ageing samples from Mexico were dominated by 1-3 yr olds, with almost none > age 6, whereas 1-8 yr olds of both sexes were well represented in U.S. samples and fish to age 15 were fairly common (Figure 4). The oldest west Gulf males were ages 9 and 23 and the oldest females were ages 11 and 24 from Mexican and U.S. waters, respectively. These noticeable differences in age and size distributions of the ageing samples are most likely an artifact of sampling. All Mexican samples were from commercial fisheries, mainly gill nets and trolling, while many of the U.S. samples were collected from recreational fishermen.

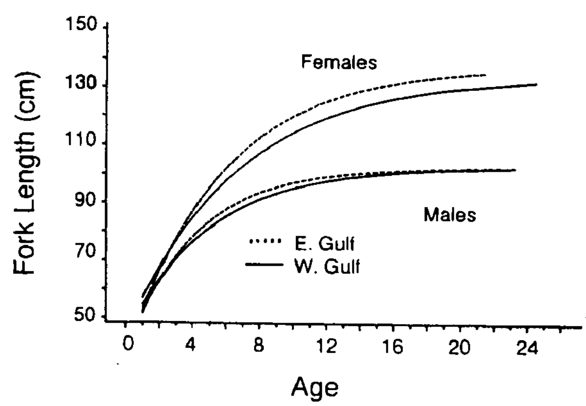

Figure 5. Von Bertalanffy growth curves for king mackerel from the eastern and western Gulf of Mexico collected during 1986 - 1992. Growth curves were calculated using individual quarterly observed sizes at age.

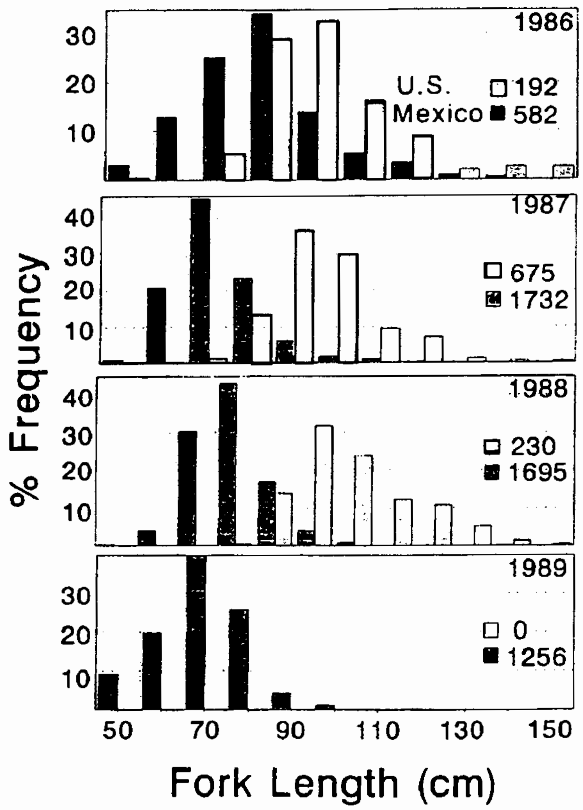

Figure 6. Annual size composition of king mackerel commercial hook and line fisheries in Mexican and U.S. waters of the western Gulf of Mexico, 1986 - 1989.

Estimates of L_∞ for E. and W. Gulf samples were 138.1 and 134.6 cm FL for females and 104.1 and 104.5 cm for males; Brody growth coefficients (k) were 0.172 and 0.149 for females and 0.253 and 0.192 for males in the same respective regions. Sample sizes for females and males were n = 2,753 and n = 1,285 in the east Gulf and n = 1,662 and n = 990 for the west Gulf.

Females grew significantly faster and larger than males ($p < 0.01$) in both regions and east Gulf fish had higher growth rates than west Gulf fish (Figure 5). Analyses indicated that most of the regional difference could be attributed to differences in the von Bertalanffy parameter t_0.

The annual size distributions of king mackerel caught by commercial hook-and-line from the Mexican and U.S. portions of the western Gulf during 1986-1989 were noticeably different (Figure 6). The mode of Mexican fish was 80 cm in 1986, then 70 cm the following three years, with very few > 80 cm. The mode of U.S. catches was 90 cm during 1986-1988, the three years for which we have data, with fish up to 120 cm fairly common. These U.S. fish were taken almost exclusively off Louisiana, an area known for large king mackerel. The 70-cm fish which dominated Mexican catches were rare in the U.S. samples.

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